Promoting Coastal Aquaculture for Adaptation to Climate Change and Saltwater Intrusion in the Mekong Delta, Vietnam

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Introduction

World aquaculture has reached total production of more than 82 million tons, and Vietnam stands as the fourth largest aquaculture producer in the world with a total production of 4.124 million tons (FAO 2020). Aquaculture is increasingly diverse and innovative, with different species, water environments, culture systems, and levels of intensification to meet typical needs and conditions. However, aquaculture is now also challenged by environmental pollution, diseases, markets and especially climate change and saltwater intrusion. The concerns of climate change, saltwater intrusion and its impacts as well as solutions for adaptation in aquaculture around the world have been studied and are well documented (Cochrane *et al*. 2009, Shelton 2014, Barange *et al*. 2018).

FIGURE 1. *Rotational rice-shrimp farming system with shrimp culture in the dry season.*

World aquaculture has reached total production of more than 82 million tons, and Vietnam stands as the fourth largest aquaculture producer in the world with a total production of 4.124 million tons. Aquaculture is increasingly diverse and innovative, with different species, water environments, culture systems, and levels of intensification to meet typical needs and conditions.

In Vietnam, especially in the Mekong Delta, with 70 percent of the aquaculture area of the country, climate change and saltwater intrusion are major concerns (ADB 2013, MONRE 2019). Vietnam, especially the Mekong Delta is one of the most vulnerable places in the world. Scenarios of climate change and sea level rise indicate that, by the end of 21st century, temperate in Vietnam will increase by 1.6-3.5 C, rainfall will increase by 2-10 percent and sea level will rise by 49-95 cm, depending on scenario. If sea level rises by 1 m, 39 percent of the natural area of the Mekong Delta will be inundated (MONRE 2012).

In recent years, the Mekong Delta has been challenged by saltwater intrusion. During the dry season, especially in 2016 and 2020, brackish water initially affected inland areas of up to 55-100 km from the coastline, causing issues in production and socioeconomics (SIWRR 2016, SIWRR 2020). Several surveys were conducted on the perceptions of farmers using different aquaculture systems in the Mekong Delta about the impacts of climate change and saltwater intrusion, as well as methods of adaptation and suggestions, give a very informative picture about the need for further and urgent actions (Anh 2014, Mai 2016).

Aquaculture and fisheries are a top priority for development in the Mekong Delta. Promoting coastal aquaculture with various species, different farming systems in specific areas are of dynamic and significant solutions to adapt to climate change and saltwater intrusion in the region. More supportive activities for further development of the industry are needed. In the last decade, many national strategies, plans, actions, decisions, resolutions on climate change and saltwater intrusion were issued and carried out. The Vietnam Government Resolution No. 120 NQ-CP (dated 17 Jan 2017) put aquaculture and fisheries as the top priorities for agri-aquaculture production structure for sustainable development of the Mekong Delta under climate change.

Shrimp Culture

Shrimp culture is one of the most important socioeconomic sectors in Vietnam. The history and development of the shrimp industry is well documented (Quynh 1992, Hai 2015). Currently, shrimp aquaculture is conducted in 736,000 ha, from which 762,000 t are produced, of which 632,000 ha and 298,000 t are for tiger shrimp and 104,000 ha and 464,000 t are for whiteleg shrimp. The Mekong Delta has 90 percent of the total shrimp culture area and 70

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FIGURE 2. *Intensive shrimp culture in lined ponds in a greenhouse.*

FIGURE 3. *Super-intensive shrimp culture in round tanks in a net-house.*

percent of shrimp produced in the country (MARD 2019). Shrimp culture is diverse, with systems such as integrated mangrove-shrimp, improved-extensive, rotational rice-shrimp, intensive and super-intensive shrimp farming systems.

Large areas of integrated mangrove-shrimp farming systems (50,000 ha) and improved-extensive shrimp farming systems (300,000 ha) in the Mekong Delta are traditional and characterized by low investment and simple management, with a productivity of 300-400 kg/ha per year, and are considered to be environmentally friendly farming systems. Under climate change, important solutions have been introduced and practiced widely such as maintaining high water levels of about 30-40 cm on the pond central platform, nursing shrimp postlarvae for larger and higher-quality seed, and diversifying the species cultured with shrimp, mud crabs, brackishwater fish and seaweeds. Production from integrated mangrove-shrimp farming systems is being certified as organic.

Rotational rice-shrimp farming systems (Fig. 1) are specific to the Mekong Delta, with over 170,000 ha of area. Under climate change and saltwater intrusion, this is considered a strategic system for agri-aquaculture production and is planned for expansion up to 250,000 ha with production of 125,000-150,000 t by 2030 (AMDI 2015). During the dry season, with brackish water (3-15 g/L salinity), shrimp are cultured with one crop of tiger shrimp (2-7/m^2), or two crops of whiteleg shrimp (5-20/m^2), or one crop of tiger shrimp and one crop of whiteleg shrimp. Shrimp are fed casually at low stocking densities or fed with pelleted feed daily at high stocking densities. During the rainy season (0-3 g/L salinity), traditional and salt-tolerant rice is cultivated and integrated with giant freshwater prawn (1-2/m^2). Rice use waste nutrients from shrimp culture for growth without or with only limited fertilizer application. Shrimp production is around 0.3-1.5 t/ha per crop (AMDI 2015, Huong 2016, Mai 2016). The system is considered to be environmentally friendly, moderate in capital investment and technical management, and especially adaptive to climate change and saltwater intrusion for food security. Recently, nursing shrimp postlarvae in plastic-lined earthen tanks with biofloc technology for two-phase shrimp culture has become very important and widely applied to improve shrimp seed quality and shorten the grow-out period as an adaptation to climate change and uncertain seasonal intrusion of saltwater (Hai *et al*. 2020). Rotational rice-shrimp farming systems are now targeted toward certification of organic production, for both rice and shrimp with large projects being implemented (MARD 2019).

In addition to the traditional and integrated systems mentioned above, the shrimp culture industry is now undergoing intensification and modernization in over 100,000 ha, with production of 5-10 t/ha per crop for intensive culture and 20-40 t/ha per crop for super-intensive culture of whiteleg shrimp. Under climate change conditions, environmental management and market requirements, big changes in technological and legal management are being implemented. Unlike conventional one-phase intensive culture systems for tiger shrimp in large earthen ponds (0.3-0.5 ha), which is very sensitive to climate change (Mai 2017), intensive and super-intensive shrimp farming is now dominated mostly by whiteleg shrimp, farmed in smaller (500-1000 m^2) HDPE-lined earthen ponds or round tanks, placed in an indoor greenhouse or outdoor nethouse (Figs. 2 and 3). Two-phase shrimp culture is mostly applied which enables multiple crops annually, shortening the culture period for grow-out, enhancing environment control and reducing the risk of disease problems. Biofloc or "semi-biofloc" is applied and enhanced mostly with sugar molasses. In many cases, discharged water is treated and reused through large storage ponds with stocked fish. Super-intensive shrimp culture is increasingly practiced by companies or entrepreneurs with good technical skill and high capital. However, household-scale farmers also apply the approach.

Results of two-phase super-intensive shrimp culture in tanks under a nethouse at a commercial company in Bac Lieu province was studied. For the first phase, whiteleg shrimp post-larvae are nursed in 100-m^3 tanks at 2500/m^3 for 16 days, with survival of 82-91 percent. Juveniles are then transferred to 500-m^3 tanks for the second phase of grow-out for 74 days, reaching very high production of 5-6 kg/m^3 (3,009 ± 346 kg per 500-m^3 tank).

Advanced recirculating systems for super-intensive shrimp culture in tanks are currently under development at Can Tho University, indicating potential for further application in the region, even at large or small scale, in rural or urban areas, to deal with climate change and to meet the need for biosecurity,

FIGURE 4. *Giant freshwater prawn culture in brackishwater ponds.*

FIGURE 5. *Rotational rice-freshwater prawn farming system in the rainy season.*

environmental friendliness and food safety. With the advance of super-intensive and high-tech shrimp culture systems, this is an important national strategy, with a target of 150,000 ha and 700,000 t produced from these type of systems by 2025 (Decision No. 79-TTg, 2018).

Mud Crab Culture

There are two species of mud crabs in Vietnam, *Scylla paramamosain* and *S. olivacea*, of which the first is more abundant (Keenan 1999, Macintosh *et al*. 2002). Mud crab culture in the Mekong Delta started in the early 1980s with different systems. Currently, grow-out of mud crab in integrated mangrove-shrimp farming systems and improved-extensive shrimp farming systems are the most important (Hai 2017). In the early stages of development, mud crab seed for farming mainly came from the wild catch or natural recruitment to farms through water supply gates. With the possibility of replacing rotifers with umbrella Artemia as a starter food, great progress was made in seed production of mud crabs, with over 600 hatcheries and 1.5 billion crablets now produced yearly in the region (Hai *et al*. 2018). Mud crab farming currently relies mainly on hatchery-produced seed of *S. paramamosain*.

In grow-out, mud crabs are stocked extensively with 500-1000 crabs/ha per month and the crabs rely mainly on natural food. Crabs are partial-harvested year-round with production of 50-150 kg/ha per year. With over 350,000 ha of culture area in the Mekong Delta, total production of mud crab in the region is about 38,000 t (Hai 2017), out of about 53,000 t produced in the whole country (Hungria *et al*. 2017). Mud crab is a euryhaline species, with a high tolerance to poor water quality and disease pathogens, and a high value for domestic and export markets. It is thus a very important candidate for culture in the coastal areas of the Mekong Delta in different systems to adapt to climate change and saltwater intrusion (Hai 2017).

Giant Freshwater Prawn Culture in Brackish Water

Giant freshwater prawn *Macrobrachium rosenbergii* is an important species in traditional freshwater aquaculture in the Mekong Delta in garden ponds or integrated with rice farming (Phuong *et al*. 2003). In recent years, prawn culture has strongly expanded in brackishwater areas of the region (Fig. 4), with a total culture area of more than 15,000 ha and production of more than 5,000 t. Prawn culture in brackish water accounts for 90 percent of the total area and 65 percent of the total production (Hai *et al*. 2017). In freshwater areas, the most common system is the alternative rice-prawn farming system (Fig. 5) in which prawns are cultured at semi-intensive levels in rice fields during the height of the rainy season, with production of about 0.5-1.5 t/ha per crop. The two main prawn farming systems in coastal areas are prawn and rice farming alternatively with tiger shrimp culture in rice fields and prawn culture in ponds alternatively with tiger shrimp culture. Prawn stocking density and production are about 1.1 ± 0.6/m^2 and 110 ± 52 kg/ha per crop for the first system; and 9.0 ± 3.6/m^2 and 886 ± 642 kg/ha per crop for the second system (Hai *et al*. 2017). Mixed-sex and all-male post-larvae are mainly supplied from local hatcheries in the region with different production systems. Water salinity during prawn culture ranges from 0-10 g/L. Giant freshwater prawn can tolerate a wide range of salinity (0-25 g/L) and grow well at 0-15 g/L (Huong *et al*. 2010). Prawn cultured in brackish water grow well, are high quality, have high resistance to diseases and provide a very good income. The coastal zone also has a large potential area of brackish water less than 15 g/L. These areas are very important to further promote the industry in the region, to adapt to climate change and saltwater intrusion, to diversify culture species and income, and especially to rotate culture species that reduce the risk of diseases and environmental problems due to over-development of shrimp culture in the area. The target for giant freshwater prawn culture industry is 50,000 ha and 55,000 t by 2025 (Decision No 79 – TTg, 2018).

Mollusk Culture

The total culture area of mollusk culture in Vietnam is 41,200 ha and production of mollusks reached 300,000 t recently (MARD 2019b). The Mekong Delta has about 60 percent of the culture area and about 31 percent of total production (MARD 2018). In the Mekong Delta, mollusk culture is popular with different

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FIGURE 6. *Raft culture of oysters in an estuary.*

FIGURE 7. *Cage culture of marine fish.*

species and systems, especially white clam culture on muddy sand beaches, blood cockle culture in mangrove-shrimp farms or on mud flats of estuaries and beaches, and oyster culture on rafts in estuaries, rivers and canals (Fig. 6).

For white clam *Meretrix lyrata* culture, the activities have been underway for many years along the coastline of the Mekong Delta. This is considered fisheries-based aquaculture and mostly under cooperatives. The culture area of each farm is about 6.4 ± 1.1 ha, which is simply fenced with nets on the beach. Although seed production of white clams is practiced around the country, clam seed for culture in the Mekong Delta are mainly from wild sources, or farmers procure seed from other places for supplemental stocking on farms. Clam culture relies entirely on natural food and tides on the beach. After 17 months of culture, white clams reach 15-20 g and are ready for harvest, with production of about 13.0 ± 1.3 t/ha per crop (Phong *et al*. 2018). White clam is an important culture species for export and the culture in some provinces have achieved Marine Stewardship Council (MSC) certification.

Blood cockle *Anadara granosa* culture is widely practiced on mudflats of estuaries or beaches, and in mangrove-shrimp farms. For culture on mudflats, blood cockle seed of 900-1000/kg collected from the wild are stocked at a density of 1-2 t/ha. After 7-12 months, blood cockle reaches 40-60/kg and are ready for harvest, with production of about 20 t/ha per crop. For blood cockle culture in mangrove-shrimp farms, seed of 700/kg are stocked at 1.5 t/ha. After six months of culture, cockles reach harvest size of 70-100/kg (Thao and Phu 2012).

Oyster *Crassostrea belcheri* culture is increasingly important and widely practiced in estuaries of most coastal provinces in the Mekong Delta where water salinity is 9-27 g/L. Culture is normally practiced with rafts of 40-1000 m^2. Different kinds of substrates are used for natural seed collection and grow-out. After 17 months of culture, oysters reach commercial size of 300-500 g. Average production is 3,560 ± 1,440 kg per crop from a 100-m^2 raft (Thao *et al*. 2018).

Generally, mollusks are an important commodity for coastal aquaculture for local markets or for export. With simple culture techniques, low capital investment, various species available, high culture potential in different conditions, this industry is increasingly important for the region. Further improvement and investment in culture technology, seed production, environmental monitoring and management are needed.

Brackishwater and Marine Fish Culture

Vietnam has a long coastline of 3260 km and thousands of islands and the Mekong Delta has over 700 km of coastline and hundreds of islands. With large areas of brackish water and seawater, Vietnam, and the Mekong Delta in particular, have great potential for brackishwater and marine fish culture. Since the early 1990s, brackishwater and marine fish culture have developed different species and culture systems: 1) extensive, integrated pond culture of mullet, milkfish and tilapia with shrimp and mud crab; 2) semi-intensive or intensive pond culture of seabass, grouper, marine goby and eel; and 3) marine cage culture of grouper, cobia, snubnose pompano, sea bream, snapper and red drum (Fig. 7). Production of brackishwater and marine fish was about 29,770 t in 2017, with a production target of 600,000 t by 2030 (MARD 2018).

In the Mekong Delta, integrated mangrove-shrimp farming systems and improved extensive shrimp farming systems are very good for integration with brackishwater fish culture. Natural fish seed may enter farms through gates during water exchange, or wild-caught fish are stocked additionally to farms. No feed is used for fish. Fish production from these systems are rather low (100-150 kg/ha per yr) but it contributes important and regular income for households. With more than 350,000 ha of these extensive systems in the region, total production of fish is considered large for local use but is not statistically recorded (Hai *et al*. 2017)

For semi-intensive and intensive fish pond culture, euryhaline and high-value fish such as goby (*Pseudapocryptes elongates*), eels (*Anguilla mamorata*), seabass (*Lates calcarifer*), Nile tilapia (*Oreochromis niloticus*) and recently spotted scat (*Scatophagus argus*) are very important culture species. Goby is cultured intensively at 80-150 fish/m^2 for 4-5 months, using pelleted feed, resulting in production of 5-16 t/ha per crop. The culture is very dynamic due to good acceptance of pelleted feed, short culture period, high yield, high profit; and fish species that are euryhaline with high tolerance of poor water quality. However, the fish seed supply remains dependent on wild-caught fry or fingerlings (Hai *et*

FIGURE 8. *Artemia culture in a salt production field.*

FIGURE 9. *Striped catfish (tra) culture in ponds in freshwater or in areas with seasonal saltwater intrusion.*

Artemia was first introduced in the early 1980s. Currently, almost 800 ha of saltfields have been switched to Artemia farming. There are more than 700 households involved and they can earn from US$3,000-8,500/ha per season, which corresponds to 3-5 times greater income compared to traditional salt production.

al. 2017). Eel culture has also been practiced in the Mekong Delta for many years, especially in Ca Mau province. Wild-caught eels of about 90-110 g are stocked into ponds at 0.9-1/m^2. Salinity during culture is around 2-5 g/L. Fish are fed with trash fish. After 14-19 months, eels are harvested at a market size of 1.3-1.6 kg, with production of 42-95 kg per 100-m^2 pond. Eels are euryhaline, high value, and grow well in ponds or tanks. However, the culture remains dependent on wild-caught seed (Long and Hai 2014). For seabass culture, pond culture of this species is practiced at household and commercial scales. Hatchery-produced fingerings are stocked at 5 ± 2 fish/m^2 in brackishwater or freshwater ponds and fed mostly with pelleted feed. After 6-7 months, fish are harvested with a yield of 20-33 t/ha (Ha *et al*. 2016). With availability of seed from hatcheries, good acceptance of pelleted feed, good growth in fresh or brackish water, and rather good price, seabass is an excellent candidate for further pond culture expansion in the Mekong Delta under climate change and saltwater intrusion.

Marine cage culture of fish in the Mekong Delta is focused mainly in Kien Giang and Ca Mau provinces, with more than 7,000 marine fish cages in the region. Each household commonly operates 4-10 wood-frame cages of 60-70 m^3 each. Cobia or grouper are stocked at 2.7 ± 1.8/m^3 or 9.5 ± 3.2/m^3, fed mostly with trash fish for about 10 months to reach harvest size of 7.8 ± 1.3 kg or 1.0 ± 0.1 kg, respectively. Fish production averages 17 ± 10 kg/m^3 for cobia and 6.5 ± 2.5 kg/m^3 for grouper (Khanh *et al*. 2015). Recently, marine fish cage culture in the region has developed at a large commercial scale with round HDPE cages for cobia, grouper and snubnose pompano. Marine fish cage culture is one of the important trends to make use of the great potential of the sea surface as well as to mitigate the impacts of climate change in the region.

Artemia Culture

With no native Artemia in Vietnam, *Artemia franciscana* strain from San Francisco Bay, USA was first introduced into the Vinh Chau saltfields (Soc Trang province) in the early 1980s as a result of a collaboration among KWT (The Netherlands), Ghent University (Belgium) and Cantho University (Brands 1992, Hoa, 2002, Hoa 2014). After a few years to adapt to the new habitat (Hoa 2002), the first harvest of more than 1 t wet weight cysts was collected (Hoa and Van 2019), with almost 90 kg/ha per 4-mo season collected in the same decade. From then, cyst production in Vinh Chau has expanded to saltfields in Soc Trang and Bac Lieu provinces and trials have also been made in other provinces in the Mekong Delta (e.g. Tra Vinh, Kien Giang, Ben Tre). Great efforts have been made to evaluate and improve Artemia farming in solar-saltworks like 1) culture system (monoculture vs. integrated system, static vs. flow-through system, one-cycle vs. multi-cycle system), 2) fertilization procedures, 3) feeding protocols and type of feed, all of which have helped increase productivity. In a suitable environments and with appropriate pond management, a pond can produce 200 kg wet-weight cysts/ha per season and, if biomass is the main harvested product, production can reach 1 t wet-weight biomass/ha per month and harvest up to 4-5 t/ha per season from a site (Brands *et al*. 1995, Anh 2009). Currently, almost 800 ha of saltfields have been switched to Artemia farming (Fig. 8). There are more than 700 households involved and they can earn from US$3,000-8,500/ha per season, which corresponds to 3-5 times greater income compared to traditional salt production. The area now produces 40-60 t of cysts and 300-400 t of wet-weight biomass annually.

The common technique for Artemia farming in the site is stocking Artemia in saltwater of 80 g/L and supplying green water from a fertilization pond as feed, sometimes with extra feeding with rice bran, fish meal, or formulated feed, as needed. Artemia will reach adulthood 2-3 weeks after inoculation and start to reproduce (either ovoviviparous or oviparous). Cysts or biomass are collected and processed prior to marketing as canned cysts or frozen biomass.

As with other aquaculture activities, Artemia farming has to cope with climate change, although saltwater intrusion is not the

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main constraint. High water temperature is the major concern because Artemia are typically grown in shallow water to facilitate the high salinity required. Moreover, water temperature is positively related to salinity so high water temperature is the major problem in Artemia culture. Several efforts have been made to address the need to reduce water temperature (e.g. increasing water depth, control of salinity, partial shading of the pond surface). Secondly, unforseen precipitation during the dry season together with cool temperatures are also a disaster for Artemia farming as the season has shortened as low salinity is more prolonged than usual. A number of technical advances have been recommended: 1) keep saltwater from last season for inoculation in the next season, 2) facilitate evaporation by pumping and raking frequently and 3) salinize sea water with crude salt, although this is more expensive than other options.

FIGURE 10. *Striped catfish (tra) culture in a raceway.*

CONSIDERING THAT CLIMATE AND SALTWATER INTRUSION ARE CRITICAL ISSUES, THE GOVERNMENT HAS BEEN EFFECTIVELY SERVING THE AQUACULTURE INDUSTRY IN THE MEKONG DELTA PARTICULARLY AND THE COUNTRY GENERALLY WITH LEGAL AND INSTITUTIONAL MANAGEMENT AS WELL AS OTHER SOLUTIONS.

Artemia farming in the Mekong Delta currently is the main subsistence for salt farmers in Soc Trang and Bac Lieu provinces compared to only salt production. However, the activity needs to be sustained, especially in the context of climate change as appropriate solutions need to pinpoint and to clarify per site/location in order to help salt farmers now become Artemia farmers for sustainable development.

Freshwater Fish Culture in Brackishwater Areas

Coastal aquaculture in the Mekong Delta is now dominated by brackishwater and marine species but is also very dynamic with many freshwater fish due to their high tolerance to saltwater up to 10 g/L, depending on species. Important species includes striped catfish (*Pangasianodon hypophthalmus*), sand goby (*Oxyeleotris marmoratus*), snakehead (*Channa striata*), snakeskin gourami (*Trichopdus pectoralis*) and Nile tilapia (*Oreochromis niloticus*).

Striped catfish culture is a big industry in the Mekong Delta with a current area of 6,600 ha and a production of 1.42 million t (MARD 2019). The culture is practiced with intensive pond culture systems (Fig. 9) at stocking density of 40-70/m^3 and production of 300-400 t/ha. Catfish culture is operated by large companies, entrepreneurs or cooperatives and mostly certified by VietGAP, GlobalGAP, BAP and ASC.

Studies on the simulated impacts of climate change and saltwater intrusion to catfish culture have been implemented and come out with valuable recommendations, especially to the catfish farming at some coastal provinces that are seasonally affected by low salinity. However, catfish can tolerate salinity up to 18 g/L and grow well at 9-12 g/L. Work on selective breeding of catfish for higher salinity tolerance and innovative culture systems (Fig. 10) are being implemented for future farming in higher-salinity brackishwater areas (Huong and Quyen 2011, Anh 2014, Phuong and Tuan 2016).

Pond culture of sand goby in Ca Mau province, at a stocking density of 0.8-2/m^2 at salinities of 1-8 g/L, gave production of 69 kg/100-m^2 pond after one year. This is a very high-value species for export and local markets (Viet *et al*. 2014, Long 2013). Snakeskin gouramy fish pond culture at 2-3 g/L of salinity produces 3-8 t/ha (Long 2013, Mai 2016).

Snakehead culture in ponds at 50-70/m^2 at 0-5 g/L salinity yields 160-190 t/ha per crop (Tuan *et al*. 2014). Snakehead is an important indigenous fish in the region that are very common but with high value in local markets. Total culture production of snakehead in the Mekong Delta is currently about 40,000 tons in different systems of pond culture, hapa-in-pond culture and indoor or outdoor tank culture (Quyen *et al*. 2017). This fish is an air-breathing species, readily accepts pelleted feed, grows well in intensive culture, easy to breed seedlings and tolerates high salinity and poor water quality. Those enable the fish to be a very important species for aquaculture under climate change and saltwater intrusion.

Outlook for Further Development of Coastal Aquaculture

Based on scenario and the status of the climate change and saltwater intrusion in the Mekong Delta as well as information from a large survey of 168 farmers on aquaculture status and perceptions, as well as the information on salinity tolerance of different species, Mai (2016) proposed a zoning map for aquaculture of various species in specific saltwater intrusion areas in the Mekong Delta. Under saltwater intrusion, aquaculture can adapt well. Diversification and selection of suitable species for culture in different saltwater-affected areas are thus necessary, based on farmers' experience and technical and local manager support.

Although well documented, for better adaptation to climate change and saltwater intrusion, more research on salinity and high temperature tolerance as well as methods of acclimation during culture for different locally potential freshwater and brackish and marine species are needed.

There have been big achievements in seed production of indigenous brackishwater and marine species (Hai *et al*. 2013) but more work is needed to improve on current results or explore new species.

TABLE 1. Current and potential species for aquaculture in different areas of the Mekong Delta affected by different salinities (Mai 2016).

Areas affected by a particular salinity range (g/L)	*Species suitable for aquaculture in the Mekong Delta*
0-4	Most freshwater fish, giant freshwater prawn
4-8	Striped catfish, snakehead, climbing perch, snakeskin gouramy, sand goby, giant freshwater prawn, tiger shrimp, whiteleg shrimp, mud crab, brackishwater fish (spotted scat, mullet, tilapia, seabass, goby, eel)
8-16	Striped catfish, sand goby, giant freshwater prawn, tiger shrimp, whiteleg shrimp, mud crab, most brackishwater fish
16-24	Tiger shrimp, whiteleg shrimp, mud crab, brackishwater and marine fish
>24	Tiger shrimp, whiteleg shrimp, mud crab, Artemia, brackishwater and marine fish, mollusks

There are currently several large national and international projects on domestication and selective breeding of different species (e.g. striped catfish, air-breathing fish, giant freshwater prawn) for better adaptation, salinity tolerance and growth in brackish water, however, more work is urgently needed.

As mentioned above, there has been good innovation in aquaculture technology in the Mekong Delta but the current farming systems need to be continuously improved at a large scale to mitigate the impacts of climate change and saltwater intrusion. Advanced systems such as modern pond culture, modern cage culture and indoor recirculating aquaculture systems should be considered and promoted appropriately.

In the Mekong Delta, there are networks for environmental monitoring and disease pathogen surveillance. It is necessary to promote this work further, to serve, interact and consult more effectively with farmers, applying the advances of the fourth industrial revolution.

Aquaculture extension activities are very dynamic in the region, training farmers about climate change and saltwater intrusion as well as solutions to mitigate impacts and adapt to climate change and saltwater intrusion are urgently needed.

Considering that climate and saltwater intrusion are critical issues, the government has been effectively serving the aquaculture industry in the Mekong Delta particularly and the country generally with legal and institutional management as well as other solutions.

Notes

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